BULK DRIVEN OFFSET COMPENSATION FOR CONTINUOUS TIME OPAMP OPERATION

Roman Prokop, Petr Novak, Vladislav Musil

Department of Microelectronics, Brno University of Technology, Faculty of Electrical Engineering and Communication, Udolni 53, 602 00 Brno, Czech Republic, phone: +420 541 146 325
e-mail: prokop@feec.vutbr.cz

ABSTRACT: Operational amplifier offset compensation is usually solved as a switched circuit that works in two phases. In the first phase the opamp compensates itself and in the second phase it normally works. Disadvantage of the type of compensation is impossibility to work continuously when application demands it.

The problem can be solved by connection of two amplifiers. The first of them (compensating one) works again in two phases. During the first one it compensates itself and during second phase it continuously compensates the second (main, working) opamp. There are more techniques that allow the continuous offset compensation of the main (or both) opamps. The bulk driven compensation is discussed in this paper.

Keywords: Operational amplifier offset compensation, bulk driven techniques

1. INTRODUCTION

Sometimes the very low voltage signals have to be processed by circuits designed in simple standard technologies. As an example the precious conductivity measurement of the electrochemical sensor can be introduced. During the measurement some determined current flows through the sensor causing corresponding voltage on it. Because of reason not to influent the measured liquid, the voltage on sensor must not exceed 100mV. Typical signal amplitude is in range from 10mV to 100mV and should be processed with accuracy lower than 3%. It is impossible to satisfy with usual operational amplifiers with about 10mV offset. An offset compensation is necessary.

2. SINGLE SWITCHED MODE COMPENSATED OPAMP

One of the possible topologies was designed in AMIS CMOS07 technology as a part of the above mentioned simple electrochemical sensor measuring system on chip. Currently the chip is processed in foundry. The schematic of the connection is shown in fig. 1. Here there is brief functionality description. During the first phase (CLK1 = 1) the opamp is connected as a follower and its input offset is stored in capacitor CC. In the second phase (CLK2 = 1) the opamp is connected as the non-inverting amplifier with gain corresponding to the resistor divider in the feedback. Voltage at the capacitor CC is added to the divider reference voltage and compensates the opamp offset. Ideally this circuit compensates fully the offset, but in reality some systematic error appears during the charging parasitic opamp input capacitance (taking charge from CC). To minimize this inaccuracy the ratio of the

opamp input capacitance and storage capacitor CC must be minimized as well as the difference between opamp input potentials in two working phases.

Sometimes the topology with capacitor located in series to the input can be used, but in this project no input current (for charging CC) was allowed.
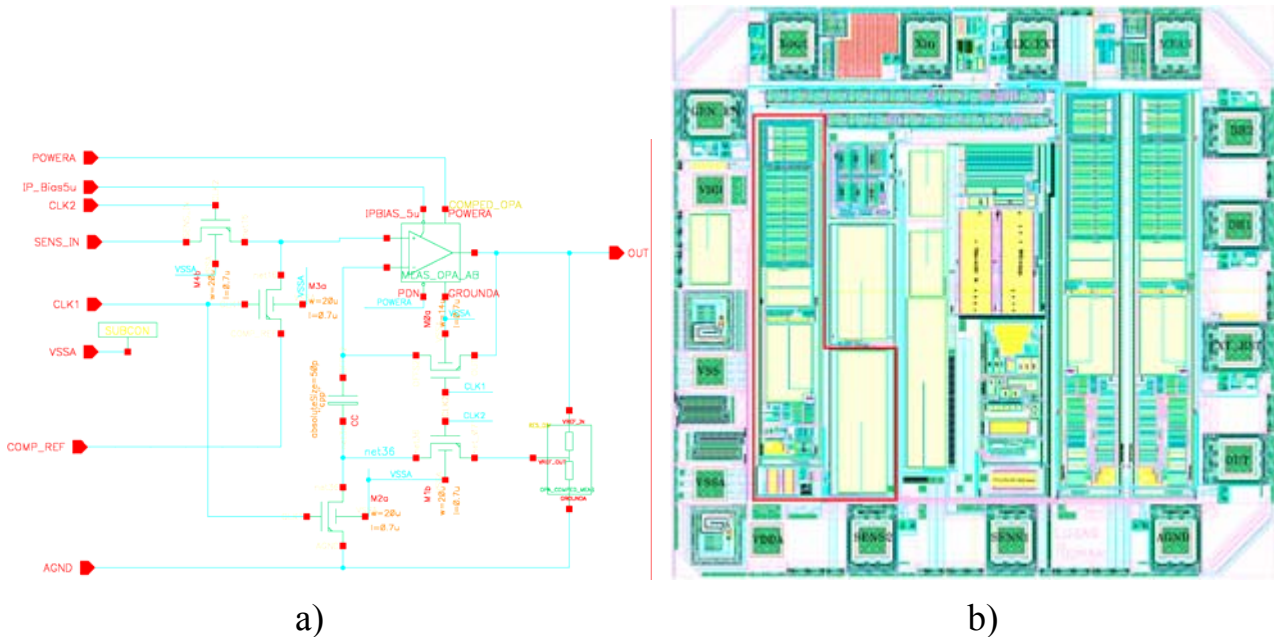

a)   b)

Fig. 1: Single switched mode compensated opamp a) schematic, b) layout (red area)

3. CONTINUOUS TIME OPERATED COMPENSATED OPAMP

Disadvantage of the type of compensation from chapter 2 is impossibility to work continuously when application demands it. It is necessary to use another technique to do offset compensation during the opamp full time operation.

The problem can be solved by an extra operational amplifier. This opamp works as the compensating one and operates again in two phases. During the first phase it compensates itself and during second phase it measures and continuously compensates the main opamp. It requires designing opamp with extra pin for offset compensation. Then the above mentioned self compensated opamp can be used as the compensating one or both amplifiers can be used with compensating pin. Principal schematic of the second case is shown in fig. 2.
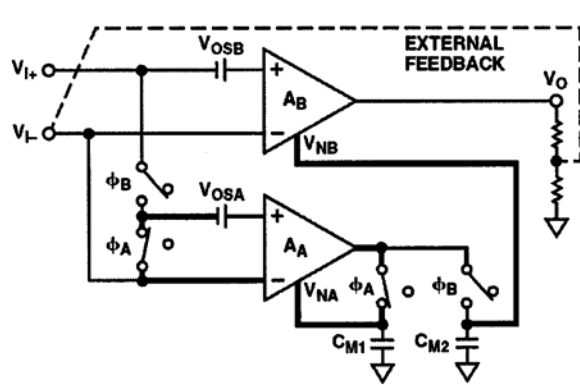

Fig. 2: Principal of the continuous time offset compensation during the first phase

During the first phase the compensating opamp A_A compensates itself and its compensating voltage is stored at C_{M1} capacitor. Once the A_A is compensated it can measure and compensated offset of the main (working) A_B during the second phase. The compensating voltage for A_B is then stored at C_{M2} and zero the V_{OSB} input offset while it's still continuously working. The final offset voltage of the structure can be theoretically calculated by the following equation:

$$V_O \approx \frac{V_{OA} + V_{OB}}{B_B} , \qquad\qquad\qquad [1]$$

where V_{OA} and V_{OB} – opamp's offset voltages
                 B_B - compensating loop gain

3.1 Bulk driven compensation principle

There are more techniques to design opamp with offset compensation by extra pin. The bulk driven compensation is chosen to be discussed in this chapter.

The principle is based on the phenomenon of the input MOS threshold voltage change by V_{bs} (bulk-source voltage) modifying. In the most usual n-well technologies it requires PMOS input pair. Threshold voltage is then given by equation 2.

$$V_{TH} = V_{T0} + \gamma(\sqrt{2.\Phi_F - V_{SB}} - \sqrt{2.\Phi_F} \, \Phi \qquad\qquad [2]$$

Where V_{T0} is threshold voltage for $V_{SB} = 0$

     γ – substrate coefficient

     Φ_F is potential of Fermi

     V_{SB} is source-bulk voltage

Dependency of the threshold voltage on V_{bs} for PMOS transistor in AMIS CMOS07 technology is shown in fig. 3. The curves for typical and worst case processes are introduced there.
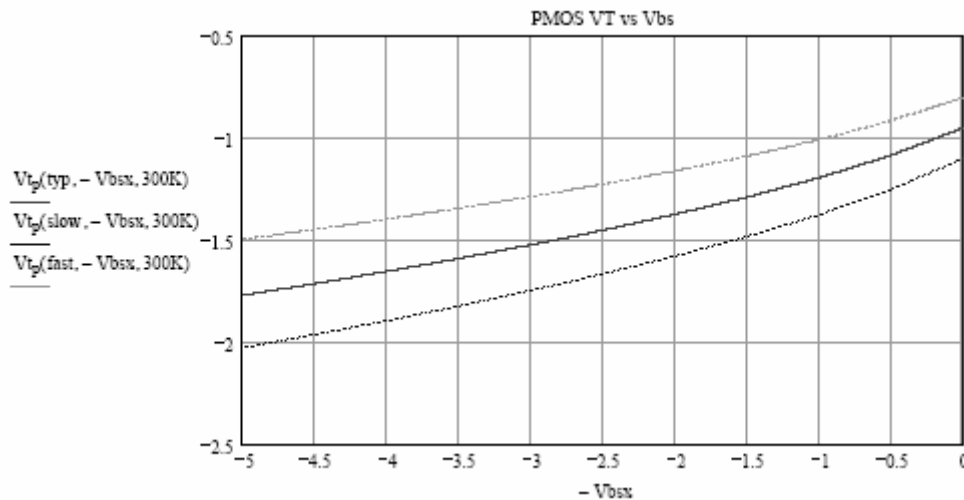

Fig. 3: PMOS V_{TH} versus V_{BS} diagram

3.2 Simple bulk driven compensated opamp

There exist more possibilities to compensate opamp offset continuously by external pin. One of them can be controlling of the current in the branch of the opamp differential transistor pair. Whereas these techniques mostly require special (sometimes quite complex) circuit topologies inside the opamp, the bulk driven offset compensation can be simply realized by using one of the input transistors bulk as the compensating terminal, in the simplest possible connection. The example of the simplest connection is shown in fig. 4. This topology is convenient for usual n-well CMOS technologies. From the schematic it is obvious the VCOMP potential should be driven close to M2 bulk (n-well) potential.
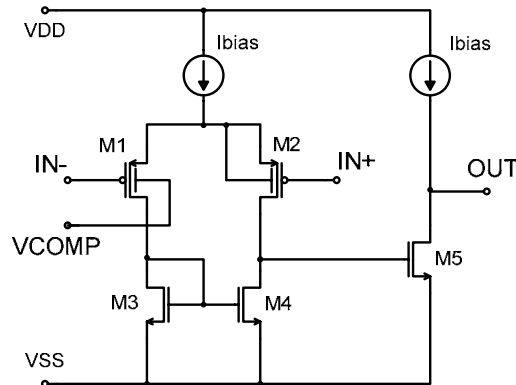
Fig. 4: Simple bulk driven compensated CMOS opamp

4. CONCLUSION

Above mentioned technique allows to effectively compensate offset of the continuously working opamp by very simple way. One disadvantage of the possible danger of latch-up is there when driving VCOMP terminal at such potential to polarize BULK-SOURCE junction in forward way. It is strongly recommended to protect this transistor against the phenomenon.

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